F1.098

UNIVERSITY OF CALIFORNIA, DAVIS

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OFFICE OF THE VICE CHANCELLOR FOR RESEARCH
(916) 752-2075
FAX: (916) 752-5432

DAVIS, CALIFORNIA 95616-8671

JUL 25 1997

CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento CA 95814

Research Proposal Entitled
"Impacts of Acid Mine Drainage on Sediment and Water Quality in the Sacramento River System"
RFP: 1997 Category III Ecosystem Restoration Projects and Programs
Principal Investigator - Gerald T. Orlob

Dear Colleague:

It is our pleasure to present for your consideration the referenced proposal in response to **the CALFED Bay-Delta Program RFP.**

Please call on the principal investigator for scientific information. Administrative questions may be directed to me or my assistant, René Domino, at the above address and phone number. We request that correspondence pertaining to this proposal and a subsequent award be sent to the Office of Research and to the principal investigator.

Sincerely,

Sandra M. Dowdy
Contracts and Grants Analyst

Enclosure

cc: G. T. Orlob

EI-098

PROPOSAL COVER SHEET

Proposal to: CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Submitting Organization:
The Regents of the University of California
University of California
Davis, CA 95616

Title of Proposed Research: Impacts of Acid Mine Drainage on Sediment and Water Quality in the Sacramento River System

Total Amount Requested	Proposed Duration	Desired Starting Date
$133,934	Eighteen Mos.	October 1, 1997
Principal Investigator:	**Department:**	**Phone Number**
Gerald T. Orlob	CEE	(916) 752-1424

Checks made payable to:
The Regents of the University of California

Send checks to:
University of California
Davis Campus
Cashier's Office, 173 Mrak Hall
Davis, CA 95616

Send Award Notice to:
Office of Research
410 Mrak Hall
University of California
Davis, CA 95616
(916) 752-2075

Approvals:

7/23/97
Principal Investigator Date

Daniel P.Y. Chang 7/23/97
Department Chair Date

7/23
Dean, College/School Date

Other Endorsement Date

JUL 25 1997
Official Signing for Organization Date

Sandra M. Dowdy
Contracts and Grants Analyst

I—002196

I-002196

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COLLEGE OF ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
(916) 752-0586
FAX: (916) 752-7872

DAVIS, CALIFORNIA 95616

July 25, 1997

Ms. Kate Hansel
CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Dear Ms. Hansel,

Enclosed please find an original plus nine copies of a proposal titled, "Impacts of Acid Mine Drainage on Sediment and Water Quality in the Sacramento River System," for your consideration for funding under the CALFED Bay-Delta Program.

If you have any questions, please call me at (916) 752-1424, or you may reach me via e-mail at gtorlob@ucdavis.edu. I look forward to receiving your reply.

Sincerely yours,

Gerald T. Orlob
Professor Emeritus
Civil and Environmental Engineering

F1-098

Proposed Project

Department of Civil and Environmental Engineering
University of California Davis

IMPACTS OF ACID MINE DRAINAGE ON SEDIMENT AND WATER QUALITY IN THE SACRAMENTO RIVER SYSTEM

Principal Investigators: Gerald T. Orlob, Professor Emeritus
Department of Civil and Environmental Engineering
University of California
Davis, CA 95616
Tel: (916) 752-1424
Fax: (916) 752-7872
e-mail: gtorlob@ucdavis.edu

Ian P. King, Professor
Department of Civil and Environmental Engineering
University of California
Davis, CA 95616
Tel: (916) 752-8386
Fax: (916) 752-7872
e-mail: ipking@ucdavis.edu

Organization type: University of California, Tax exempt

Tax Identification no.: 94-6036494-W

Financial Contact Person: Ms. Stephanie Reynolds
Office of Research, College of Engineering
University of California
Davis, CA 95616
Tel: (916) 752-7405
Fax: (916) 752-8058
e-mail: sareynolds@ucdavis.edu

Collaborators: California Department of Fish and Game, field assistance
United State Geological Survey, data assistance

RFP Project Type: Group 3, Services and Other projects

F1098

Executive Summary

IMPACTS OF ACID MINE DRAINAGE ON SEDIMENT AND WATER QUALITY IN THE SACRAMENTO RIVER SYSTEM

Gerald T. Orlob and Ian P. King, Principal Investigators
Department of Civil and Environmental Engineering
University of California, Davis

A. Project Description

The quality of water delivered to the Sacramento River from Keswick Reservoir is governed by the physical and operational characteristics of the Shasta-Trinity Division of the Central Valley Project (CVP) and discharges of acid mine drainage from historic mining activities in the surrounding region. Variations in daily releases from Spring Creek Power Plant coupled with reduced elevations in Keswick Reservoir can induce velocities through the Spring Creek Arm of Keswick Reservoir that are often sufficient to scour previously deposited sediments containing mixtures of bound and dissolved contaminants, potentially compromising the attainment of water quality objectives and threatening the aquatic ecosystem in the river downstream. Additionally, studies of sediment deposits in Keswick Reservoir by the USGS reveal the presence of sediment-bound copper and heavy metals that may be mobilized by resuspension and transported to downstream locations. Therefore, control of heavy metal loading and its distribution between the water column and sediments is critical for maintaining viable and sustainable populations of aquatic organisms in the Sacramento River, and particularly those species of greatest concern, including the winter- and spring-run chinook salmon. Assessment of contaminant concentrations in the water column and sediments that are discharged from upstream sources into the Sacramento River requires characterization of the physical and chemical processes driving their distribution in the aquatic environment. Consequently, there is a need for a reliable capability to predict the fate and transport of sediments and toxic substances under the conditions of actual project operation. This proposal specifically addresses these needs through application of hydrodynamic and water quality models developed to examine the fate and transport of copper and sediments in Keswick Reservoir and models for simulation of water quality in the Sacramento River.

Primary Ecological Objectives

The primary objective of the proposed study is to provide an improved, physically-based understanding of the dynamic behavior of the transport and fate of sediments, copper and other heavy metals in the Sacramento River. This requires developing an analytical method for estimating the concentrations of specified contaminants (e.g. heavy metals) in the water column and sediments, and measuring physical properties of contaminated sediments in the system to identify concentrations of heavy metals present in the water column and their distribution into sediments.

B. Project Approach

The proposed project will include a modeling component to simulate hydrodynamics and water quality in the river-reservoir system combined with a study of the physical properties and behavior of sediments in the Spring Creek Arm and in the study reach of the river.

1. Hydrodynamic and Water Quality Modeling. Physically-based predictive tools that are operational for the Sacramento River system include mathematical models to simulate reservoir

hydrodynamics (velocities and water depths), sediment transport, and copper transport and transformation in Keswick Reservoir, and one-dimensional hydrodynamic and water quality (temperature) models of the main stem of the Sacramento River. The models will be combined to include both Keswick Reservoir and the upper reach of the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam to evaluate the transport and fate of fine sediments, copper and other heavy metals discharged to the river.

2. Sediment Sampling. This component of the project will focus on characterizing sediment release rates as a function of flow using sediment samples from the Spring Creek Arm of Keswick Reservoir and the Sacramento River. Flume studies will be conducted to measure sediment resuspension rates and to quantify the relationship between sediment resuspension and flowrates in the overlying water column.

Schedule

It is anticipated that the study will be completed within eighteen months from the date of project inception.

C. Project Justification for CALFED Funding

This project meets the objectives of the CALFED Program to evaluate effects of contaminants discharged with acid mine drainage on water quality in the Sacramento River where they may affect priority species of concern, e.g., winter- and spring-run chinook salmon.

D. Budget Costs and Third Party Impacts

The estimated cost of the proposed project is $133,934 for a two year period. No third party impacts are anticipated as a result of work conducted on this project.

E. Applicant Qualifications

Dr. Orlob, Professor Emeritus and Dr. King, Professor, in the Department of Civil and Environmental Engineering at the University of California, Davis, have extensive research and project experience in development and application of systems analysis techniques, especially mathematical models of surface water systems, for water quality management. Most recently, their research has focused on temperature control in northern California river systems including the Sacramento, Trinity, Feather, Shasta, and Klamath rivers and the Sacramento-San Joaquin Delta. They guide a team of doctoral and masters students experienced in field techniques and application of hydrodynamic and water quality models to riverine, lake, reservoir, and estuarine surface water systems.

F. Local Support

The proposed project will greatly benefit from field monitoring equipment and expertise acquired during on-going projects at UC Davis. In addition, the investigators anticipate continued collaboration with the California Department of Fish and Game for limited field assistance, and other state and federal agencies for field data available for the Sacramento River watershed.

IMPACTS OF ACID MINE DRAINAGE ON SEDIMENT AND WATER QUALITY IN THE SACRAMENTO RIVER SYSTEM

A. PROJECT DESCRIPTION

The quality of water delivered to the Sacramento River from Keswick Reservoir is governed by the physical and operational characteristics of the Shasta - Trinity Division of the Central Valley Project (CVP) and discharges of acid mine drainage from historic mining activities in the surrounding region. Releases from Whiskeytown and Shasta Reservoirs for CVP purposes provide dilution of toxic-laden discharges from the Spring Creek Debris Dam during normal operation. Variations in daily releases from Spring Creek Power Plant coupled with reduced elevations in Keswick Reservoir can induce velocities through the Spring Creek Arm of Keswick Reservoir that are often sufficient to scour previously deposited sediments containing mixtures of bound and dissolved contaminants, potentially compromising the attainment of water quality objectives and threatening the aquatic ecosystem in the river downstream.

In recent years, regulation of toxic inflows and local treatment of mine wastes have significantly reduced loadings of heavy metals (by as much as 70 to 80 percent), thereby decreasing acute toxicity effects (i.e., fish kills) associated with normal runoff events and diminishing the likelihood of adverse conditions during the most extreme runoff events. However, long-term exposure of aquatic life in the river to concentrations of dissolved copper and other heavy metals below acute toxicity thresholds continue to pose chronic toxicity threats to sensitive aquatic organisms in the Sacramento River. Long-term exposure to sub-lethal concentrations of heavy metals may result in physiological damage to juvenile salmonids indigenous to the river system below Keswick Dam. Additionally, studies of sediment deposits in Keswick Reservoir by the United States Geological Survey [California Dept. of Fish and Game, (R. W. Fujimura, C. Huang and B. Finlayson), "Chemical and Toxicological Characterization of Spring Creek Sediments", 1995] reveal the presence of sediment-bound copper and heavy metals that may be mobilized by resuspension and transported to downstream locations. Therefore, control of heavy metal loading and its distribution between the water column and sediments is critical for maintaining viable and sustainable populations of aquatic organisms in the Sacramento River, and particularly those species of greatest concern in the river including the winter-run and spring-tun chinook salmon.

Assessment of concentrations of contaminants in the water column and sediments that are discharged from upstream sources into the Sacramento River requires characterization of the physical and chemical processes driving their distribution in the aquatic environment. Consequently, there is a need for a reliable capability to predict the fate and transport of sediments and toxic substances under the conditions of actual project operation. This proposal specifically addresses these needs through application of hydrodynamic and water quality models developed to examine the fate and transport of copper and sediments in Keswick Reservoir and models for simulation of water quality in the Sacramento River.

Hydrodynamic and Water Quality Modeling. Physically-based predictive tools that are operational for the Sacramento River system include mathematical models to simulate reservoir hydrodynamics (velocities and water depths), sediment transport, and copper transport and transformation in Keswick Reservoir. The basic modeling methodology has already been successfully demonstrated

by dynamic simulations of flow and water temperature in the Sacramento River under actual system operating conditions. Recent field studies (conducted under the National Water Quality Assessment (NAWQA) program conducted by the United States Geological Survey) show elevated concentrations of copper and other heavy metals in the sediments in the upper reach of the Sacramento River. The findings of their study emphasize a need for developing a modeling system which includes Keswick Reservoir and the Sacramento River, for use in management of contaminant discharges to the river.

It is proposed that present mathematical modeling capabilities be extended to include both Keswick Reservoir and the upper reach of the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam to evaluate the transport and fate of fine sediments, copper and other heavy metals discharged to the river. This reach of the river provides critical spawning habitat for salmon, a priority species identified in the Sacramento River. The extended model will provide a valuable management tool for assessment of measures for controlling fine sediment and heavy metal (e.g., copper, cadmium and zinc) discharges from acid mine drainage to enhance water quality and ecosystem health in the Sacramento River system.

Sediment Sampling. Sediments in the Spring Creek Arm of Keswick Reservoir exhibit unique characteristics associated with the high percentage of heavy metal precipitate ('floc') in the sediments. Physical properties and behavior of the material may differ from cohesive (mud) and non-cohesive (sand) sediments more commonly found in natural systems. Observed physical characteristics of sediments in the Spring Creek Arm include loosely packed material in the surface sediment layers, fine material in deeper layers, and variation in the thickness of sediment deposits depending on the location in the arm.

It is proposed that a preliminary investigation be carried out as a component of the proposed study to characterize sediment release rates as a function of flow through the Spring Creek Arm. The preliminary investigation will include a field component in which sediment samples from the Spring Creek Arm of Keswick Reservoir and the Sacramento River will be gathered, and a laboratory component in which flume studies will be conducted to measure sediment resuspension rates and to quantify the relationship between sediment resuspension and flowrates in the overlying water column, for at least two different types of bed materials (densely vs. loosely packed) obtained from the Spring Creek Arm, and sediments from the Sacramento River in the reach above Red Bluff Diversion Dam.

OBJECTIVES

The primary objective of the proposed study is to provide an improved, physically-based understanding of the dynamic behavior of the transport and fate of sediments, copper and other heavy metals in the Sacramento River. This requires developing an analytical method for estimating the concentrations of specified contaminants (e.g. heavy metals) in the water column and sediments, and measuring physical properties of contaminated sediments in the system to identify concentrations of heavy metals present in the water column and their distribution into sediments at various locations throughout the study reach and at times of heightened sensitivity of indigenous aquatic species, e.g., juvenile salmonids.

B. Project Location

Keswick Reservoir and the upper reach of the Sacramento River are a part of the Sacramento River watershed, extending from Shasta to Tehama County, California, shown in Figure 1. The system boundaries proposed for modeling purposes extends from Shasta Dam downstream to the Red Bluff Diversion Dam, and includes sub-models for Keswick Reservoir and the Sacramento River. Field sampling will be conducted in the Spring Creek Arm of Keswick Reservoir and in the Sacramento River below Keswick Dam.

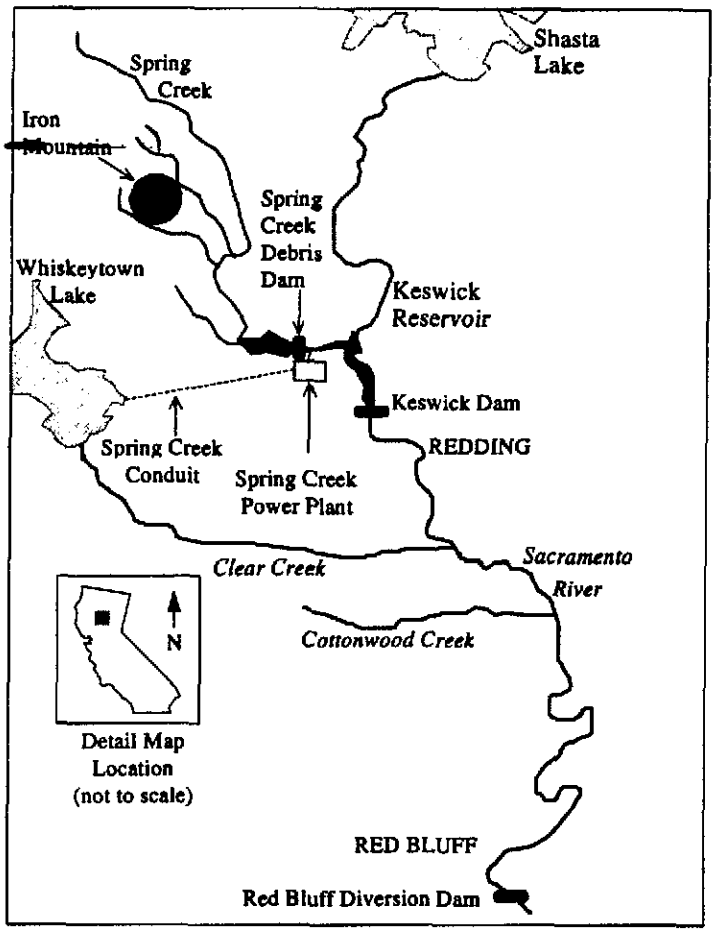

Figure 1 Location schematic of Keswick Reservoir and the upper reach of the Sacramento River

C. Expected Benefits

Concentrations of copper and other heavy metals discharged with mine drainage into the Sacramento River system are the primary stressors that will be evaluated in the proposed study. The primary benefits of the proposed project include an improved understanding of the fate and transport of heavy metals (particularly copper) discharged with mine drainage into Keswick Reservoir and to the critical salmon-spawning reach in the Sacramento River above the Red Bluff Diversion Dam. The proposed project will provide a methodology for quantifying water column and sediment concentrations of metals and sediment deposition patterns in the reservoir and river, necessary for management of reservoir operations and water quality in the river.

Products of the proposed work will include functional mathematical models to be used as water quality management tools for simulating hydrodynamics and water quality in Keswick Reservoir and the Sacramento River under a variety of operating and loading conditions, and for systematic evaluation of proposed changes in system operations.

D. Background and Technical Justification

Elevated concentrations of heavy metals, particularly copper, exist in sediments in Keswick Reservoir and the upper reach of the Sacramento River and there is a high potential for mobilization of these contaminated sediments under existing hydrologic and reservoir operation conditions. Control of heavy metal loading and its distribution between the water column and sediments is critical for maintaining viable and sustainable populations of aquatic organisms in the Sacramento River. A physically-based approach is proposed for assessing concentrations of contaminants in the water column and sediments in this section of the Sacramento River system. This modeling approach takes into account hydrologic and operational changes in the system, is based on the actual system geometry, and includes components for simulation of sediment transport and the transport and speciation of heavy metals discharged with mine drainage.

The field and laboratory components of the proposed study are necessary for examining settling and erosion behavior of sediments under existing flow conditions, particularly in the Spring Creek Arm of Keswick Reservoir, which receives releases from the Spring Creek Power Plant. In combination, the field and modeling components of the proposed project will provide a reliable methodology for evaluating the effects of alternative hydrologic, operation, and mine drainage loading conditions on concentrations of metals in the Sacramento River system.

The proposed project is a continuation of two separate projects. The first project includes two-dimensional hydrodynamic and water quality models adapted to Keswick Reservoir and contains capabilities for modeling sediments and speciation of copper. The project was funded under a two-year grant from the Water Resources Center of the University of California and is near completion as the dissertation research for a doctoral student. The second project includes one-dimensional hydrodynamic and temperature models of the Sacramento River from Keswick Dam downstream to Verona. The model of the river was completed, including calibration and verification, as part of the Sacramento River Temperature Study [Deas, *et al.*, 1996] funded under Section 205j of the Clean Water Act.

E. Proposed Scope of Work

To meet the objectives listed above in developing an improved understanding of the transport and fate of contaminants in the Sacramento River and to provide analytical tools for their control, it is necessary to complete certain specific tasks, outlined as follows:

Task 1: Assemble and review relevant data and information

Purpose: To gather physical and chemical data to be used in application of the models.

Relevant data include river cross-sections and bathymetry necessary to represent the system geometry. As part of a study recently completed at the University of California, Davis, temperature

in the Sacramento River was modeled using one-dimensional hydrodynamic and water quality models. Cross-sections and river geometry that were described in significant detail in that study will be available for use in the proposed contaminant transport study.

Other relevant data to be assembled include historic observations of hydrology, gaged flows and water surface elevations, water quality, and water column and sediment metals concentrations. Data will be necessary to characterize properties and behavior of the riverine sediments subject to transport. Specific attention will be given to the utility of these data for use in calibration and verification of the models. Reservoir operation and performance criteria will be identified as they affect contaminant transport in the river.

Task 2: Field Monitoring

Purpose: To supplement existing data and provide more detailed characterization of the critical reach in the Sacramento River above Red Bluff Diversion Dam.

Conduct water quality and sediment sampling in the critical study reach to fill data gaps in sufficient spatial and temporal detail to describe contaminant distributions in the water column and sediments.

Task 3: Flume Studies

Purpose: To evaluate sediment settling and resuspension rates under a range of flow conditions.

Conduct flume studies to measure sediment resuspension rates and derive relationships between flow rates and sediment deposition and resuspension for at least two different types of bed materials (densely vs. loosely packed) obtained from the Spring Creek Arm, and sediments from the Sacramento River. A recirculating flume is available at the UC Davis Hydraulics Laboratory for use in this study.

Task 4: Model Development

Purpose: To adapt hydrodynamic and water quality models to Keswick Reservoir and the Sacramento River.

There exists a well-developed foundation for this component of the study: hydrodynamic and water quality models of Keswick Reservoir and the Sacramento River have been developed as part of separate studies of these two systems. Representations of the reservoir and river have been constructed in sufficient spatial detail to describe the important features of the prototype systems. A series of test runs will be made for the combined models to check their performance over a range of expected system operation scenarios. Results will be evaluated for consistency with actual field observations.

Task 5: Model Calibration, Verification and Sensitivity Analysis

Purpose: To complete model development and testing.

Since the model is an approximation of the actual system, model calibration is an important process in development. Different model coefficients are adjusted systematically within acceptable ranges of values until model performance represents, as closely as possible, the behavior of the

prototype system. Model performance is measured in terms of the ability to accurately predict key response variables, including velocities and water quality constituent concentrations. Once calibration is achieved within acceptable limits, then verification of the model is performed using a new data set, while keeping constant the coefficients determined by model calibration. Model performance is again evaluated. Sensitivity testing will determine model response to incremental changes in model coefficients and boundary conditions. Verification and sensitivity analysis provide measures of the models' reliability in representing the system.

Task 6: Model Application

Purpose: To apply the models systematically to evaluate system behavior under different boundary conditions.

The models will be operated under a range of specified boundary and loading conditions. Different alternatives may include current, expected, or 'worst-case' reservoir operation and loading conditions, which may lead to elevated concentrations of contaminants in the Sacramento River throughout the reach from Keswick Reservoir downstream to the Red Bluff Diversion Dam.

Task 7: Project Documentation

Purpose: To document the study methodology and results.

A detailed report will be presented at upon conclusion of the study, containing descriptions of methods used, discussions of alternative hydrologic, reservoir operation, and loading conditions considered and the system response to each alternative.

F. Monitoring and Data Evaluation

Please see tasks 2 and 3, above.

G. Implementability

The investigators will collaborate with the California Department of Fish and Game and other agencies responsible for ensuring water quality in the Sacramento River to ensure environmental compliance when collecting sediment samples. Other impacts, permit requirements, etc. are not anticipated for any other components of the proposed project.

PROJECTED COSTS AND SCHEDULE

A. BUDGET

		1st Year	2nd Year
A.	Personnel		
	1 Principal Investigator; 12 mo. @ 10% (no charge)	$0	$0
	2 Co-principal Investigator; $7,306; 9 mo. @ 5% (1st yr.)	$3,288	
	Co-principal Investigator; $7,672; 9 mo. @ 5% (2nd yr.)		$3,452
	3 PGRE V, non-student; $2905; 18mo. @50%	$17,430	$8,715
	4 PGRE II, student;		
	$2,443; 9 mo. @ 50%, 3 mo. @ 100% (1st yr.)	$18,323	
	$2,492; 6 mo. @ 50% (2nd yr.)		$7,476
	5 Undergraduate assistant; $1000 @ 3 mo.,$400 @ 9 mo.	$6,600	$6,600
	Subtotal, personnel	$45,641	$26,243
B.	Fringe Benefits		
	0.24 x (A3)	$4,183	$2,092
	0.089 x (A1+A2)	$292	$307
	0.038 x (A4+A5)	$948	$535
	Subtotal, benefits	$5,432	$2,934
C.	Student Fees	$4,485	$4,709
D.	Travel	$1,000	$1,000
E.	Supplies	$1,000	$1,000
F.	Equipment[1,2]	$3,000	$0
G.	Overhead 0.445 x (A + B + D + E) (out-of state or federal contract rate)	$23,617	$13,873
	Project Total, by year	$84,175	$49,759

Total proposed budget $133,934

Notes:

[1]Equipment:

Flume modifications (Screens, attachments for installment)	$2,000
Sediment dredge	600
Sediment core sampler	400
Equipment total	$3,000

[2]Equipment: The project will benefit from use of equipment already acquired by the investigators including a Marsh McBirney velocity meter, a Hydrolab H20 water quality sampling meter, and different items for characterizing channel depths and cross-sections.

B. SCHEDULE MILESTONES

Task	Months from project start																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Data gathering	xx	xx																
Field program preparation and implementation			xx	xx	xx	xx	xx											
Flume studies					xx	xx	xx	xx	xx									
Model adaptation				xx	xx	xx	xx	xx	xx	xx	xx							
Model calibration, verification, and sensitivity										xx	xx	xx	xx					
Model Application													xx	xx	xx	xx	xx	
Progress reports				xx				xx				xx				xx		
Documentation																	xx	xx

C. THIRD PARTY IMPACTS

No third party impacts are anticipated as a result of this project.

APPLICANT QUALIFICATIONS

Gerald T. Orlob, Principal Investigator

Dr. Orlob is presently Professor Emeritus of Civil and Environmental Engineering at the University of California at Davis. He holds degrees in Civil, Environmental and Hydraulic Engineering, and is a registered Professional Engineer in California. Throughout a career in professional practice, engineering education and research, Dr. Orlob has specialized in the development and application of systems analysis techniques, especially mathematical models of surface water systems, for water quality management. He has published widely in the technical literature. His contributions in his field of specializations have been recognized by awards from professional and scientific organizations. He is a member of the National Academy of Engineering. As an emeritus professor at UC Davis, he continues active participation in research related to water quality issues, recently focused in temperature control in Northern California river systems including the Sacramento, Trinity, Feather, Shasta, and Klamath rivers and the Sacramento-San Joaquin Delta.

Ian P. King, Co-Principal Investigator

Dr. King is presently Professor Emeritus of Civil and Environmental Engineering at the University of California at Davis. He holds BS and MS degrees in Civil and Structural Engineering and a Ph.D. in Engineering Mechanics. In addition to teaching and research related to hydromechanics and water quality, Dr. King has wide experience in private professional practice concerned with the development and application of mathematical models for simulation of surface water systems. He is the original developer of a suite of finite element models that are being widely applied to characterize the hydrodynamic behavior of rivers, lakes and reservoirs, estuaries, and coastal environments. These models form the basis for water quality simulation in such systems. At UC Davis, Dr. King teaches in the undergraduate and graduate programs in water resources and environmental engineering and is engaged with his students in research related to water resources management. His recent research has been concerned with extension of the finite element method to solution of complex three-dimensional flow fields.

Camilla M. Saviz, Project Manager

Ms. Saviz is presently a doctoral candidate in the Department of Civil and Environmental Engineering at the University of California at Davis. She holds BS and MS degrees in Mechanical Engineering and an MBA degree in general management. While pursuing her doctoral degree in Civil Engineering at UCD, Ms. Saviz has been engaged as a post-graduate research engineer, working on several projects related to analysis and modeling of hydrodynamics and water quality. Her dissertation research has focused on implementation of two-dimensional hydrodynamic and water quality models to examine the fate and transport of copper discharged with acidic mine drainage into Keswick Reservoir. The product of her research will be used to evaluate alternatives for managing reservoir operations and contaminant discharges to the Sacramento River.

Item 8

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California

OFFICIAL'S NAME: Sandra M. Dowdy
Contracts and Grants Analyst

DATE EXECUTED: JUL 25 1991

EXECUTED IN THE COUNTY OF: Yolo

PROSPECTIVE CONTRACTOR'S SIGNATURE: Sandra M. Dowdy

PROSPECTIVE CONTRACTOR'S TITLE:

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA